elements of the problem that the advantages of the hoop system can be properly developed.

In illustration of this we refer to three diagrams of Sir Joseph Whitworth's 12-inch steel gun. The first, C_1, shows the strains, if the hoops are put in with no initial strain, that is to say, if each hoop is an exact fit to the one below it, which is Sir Joseph's present practice. The gun in this state is in the same condition under internal pressure as a homogeneous or solid gun of steel. The tensions with an initial pressure of 24 tons per square inch would be 28·18 tons and 2·3 tons per square inch at the inner and outer circumference respectively. The second diagram, C_2, would be the state of the strains, if the Woolwich rule of a uniform shrinkage of 1 in 1000 were adopted. The inner tube and the first hoop would never be out of compression, the second hoop would be strained to 8·44 tons and 3·85 tons, the third ring to 17·40 tons and 12·84 tons, and the fourth ring to 27·64 tons and 22·82 tons at the inner and outer circumferences respectively.

The third diagram, C_3, shows the gun as it would be strained if the initial shrinkages had been properly calculated and applied. For every hoop the tension of the inner circumference would be 10 tons per square inch, whilst that of the outer circumferences would be 1 ton compression for the tube, 4·11 tons, 6·51 tons, 7·72 tons, and 8·82 tons for the hoops respectively.

Thus it is seen that by a multiplication of hoops with initial strains properly applied the maximum strain is reduced from 28 tons to 10 tons per square inch. But on the other hand, by the Woolwich rule of a uniform shrinkage of 1 in 1000, some of the hoops would be always under compression, whilst others would be more or less strained, and the maximum would attain nearly the same as in the homogeneous gun—28 tons per square inch. Another remark must here be made. Referring to diagram C_3 it is seen that in the case of each hoop the strain decreases rapidly from the inner to the outer circumference. Thus in the first hoop the strain decreases from 10 tons to 4 tons, in the next from 10 tons to $6\frac{1}{2}$ tons, and so on. Now by greatly increasing the number of hoops and consequently decreasing the thickness of each, the strains on the outer circumference may be brought very nearly up to the same strain as the inner circumference, and this is what is attained by the use of *wire*. A coil of wire is but a very thin hoop, and if, instead of a hoop of $4\frac{1}{2}$ inches of steel, 36 coils of wire of $\frac{1}{8}$th inch had been used, the difference of strain between the inner and outer circumference of each coil would be inappreciable, and the whole thickness of the gun would have been uniformly strained, and the maximum strain would not have exceeded 6 tons per square inch, or if the wire were strained to 10 tons per square inch the thickness of the gun might be reduced from $22\frac{3}{4}$ to $13\frac{1}{2}$ inches.

But this is not all the advantage of the use of wire. Wire of small section is greatly stronger than the same material in mass. It is within the truth to say that steel which in mass might be safely strained to 15 tons per square inch, might in the form of wire be strained to 30 tons per square inch. Consequently the wire gun would be as safe under a strain of 20 tons as the hoops under 10 tons, and therefore the thickness of a wire gun of equivalent strength to that represented in diagram C_3 might be reduced to $6\frac{3}{4}$ inches instead of $22\frac{3}{4}$ inches.

From the preceding remarks and the diagram of Whitworth's 12-inch gun, it will be seen how very important is the question of the degree of shrinkage in built up guns. It is worth while to dwell a little longer upon this question, and to illustrate it we now give diagrams showing how the strength of a gun may be reduced by a small difference in the shrinking such as would be caused by a slight error in the dimensions of one of the hoops, due either to miscalculation, imperfect workmanship, or irregular contraction in cooling. The diagrams D_1 and D_2 represent the strains on the hoops of an 8-inch gun, built up of an inner tube and three concentric hoops of iron having an elastic limit of 12 tons per square inch. D_1 shows the strains when the gun is completed and free from internal pressure, on the hypothesis that the shrinkages are correctly calculated and accurately worked too. The tube and first hoop are in compression, the two outer rings in tension. D_2 represents the strain when subjected to internal pressure, so as to make the maximum strain 12 tons per square inch, and it is seen that all the hoops are equally strained up to the elastic limit. D_3 shows the strain in the same gun on the hypothesis that either from miscalculation or inaccurate workmanship the outer hoop has been made 1/500th of an inch too small, and when by internal pressure the maximum strain reaches 12 tons per square inch.

It is apparent at a glance what a great difference this error has made in the distribution of the strains. Without going into detail, it may be stated that the strength of the gun has been reduced 40 per cent. by the small error of 1/500th of an inch in one of the hoops. Accurate workmanship is, however, only one of the difficulties to be encountered in shrinking on hoops. Different qualities of iron shrink differently in cooling from the same temperature; moreover they do not shrink back in all cases to the size from which they were expanded, but to a somewhat smaller size. This depends on the temperature to which they have been heated. Moreover the shrinkage varies according to the number of times they have been heated. For instance, a wheel tier 7 feet diameter was heated red-hot, and cooled thirteen times in succession with the following results:—

1st	time	it contracted	$\frac{5}{8}$	in.	in length.
2nd	,,	,,	$\frac{11}{16}$	,,	,,
3rd	,,	,,	$\frac{7}{16}$	,,	,,
4th	,,	,,	$\frac{5}{8}$	,,	,,
5th	,,	,,	$\frac{3}{8}$	,,	,,
6th	,,	,,	$\frac{1}{4}$	,,	,,
7th	,,	,,	$\frac{1}{4}$	,,	,,
8th	,,	,,	$\frac{5}{8}$	,,	,,
9th	,,	,,	$\frac{1}{4}$	,,	,,
10th	,,	,,	$\frac{1}{4}$	,,	,,
11th	,,	,,	$\frac{5}{8}$	,,	,,
12th	,,	,,	$\frac{1}{4}$	,,	,,
13th	,,	,,	$\frac{1}{8}$	,,	,,

Thus altogether it contracted $5\frac{3}{8}$ inches from its original length of 22 inches.

It is clear therefore that however accurate the calculation and workmanship, there must be great difficulty in ensuring the exact amount of tension in this system of gun construction, and if guns are made without regard to calculation, without regard to the peculiar idiosyncracy of the iron, and without regard to the temperature from which the shrinking is made (and such is pretty much the case at Woolwich), it is no wonder that they split their tubes or shift their hoops in action. Many Woolwich guns have done this even under trial, and it is not improbable that in the late operations at Alexandria two of the guns of the *Alexandra* were injured in this way.

Another objection to this method of gunmaking is the possibility of latent defects in the hoops. It is impossible always to detect a flaw, even of considerable magnitude, in a hoop of iron or steel 10 to 18 inches thick such as are used in the large Woolwich guns, and such latent flaws may prove fatal to the gun even if in other respects it were properly constructed.

JAMES A. LONGRIDGE

(*To be continued.*)

MR. FORBES' ZOOLOGICAL EXPEDITION UP THE NIGER

MR. W. A. FORBES writes from Lokoja, on the Niger, at the confluence with the Binué (September 9) as follows:—I have been here on and off

about a fortnight, and have been up the Binué as far as Loko, about 100 miles, where I got some birds. Altogether up to the present I have seen or got about 80 species of birds, including *Scopus*, *Plotus*, *Indicator*, and *Rynchops*; as yet no *Podica*, *Irrisor*, or Musephagidæ. Of Hornbill I have seen 3 or 4 species, but they are very shy, and as yet I have not shot one. Ploseine birds are the feature here; about 1-3rd of the species are of that family, and some I have are good ones, especially *Estrelda nigricollis* and *E. rara*, both of them discovered by Heuglin. These and other things make me fancy that we are out of the true West African region here; the antelopes seem also eastern. There are 4—5 here, including a brown *Hippotragus*, and what I fancy is *Alcelaphus tora*. I have skins and horns of these, and shall get others. *Bos brachyceros* is common here, but as yet I have only seen spoor, not the beast itself. We saw lots of Hippopotamuses coming up, and I killed the second I shot at, but could not recover the body.

I have also killed a large crocodile, 15 feet long, apparently *C. acutus*. I have also a few fishes and reptiles, and shall get more I hope. Butterflies are not very numerous at present, and the country is too open for them, being, generally speaking, a large grassy plain, with lots of isolated trees, not very big, and bushes. There is no regular thick forest up here at all, and even in the lower river, in the delta, it is nothing like the Neotropical forests. The weather has been very dry, and the river is still rising. After leaving Bidda our plans are uncertain. Mr. M. talks of going on to Sokoto, if he can get away from his stock-taking, and if he goes I shall probably go too. If not, I shall try and stay some time at Ischunga, a station a little off the river above Egga.

We are happy to be able to add that Mr. Forbes was in excellent health at the date of his letter.

WORK IN THE INFRA-RED OF THE SPECTRUM

It is with a certain amount of dread of boring the readers of NATURE, that I have taken up my pen to write on the method of photographing with rays of very low refrangibility, since it ought to have passed the limits of novelty. And yet I suppose it has not altogether done so, since almost weekly, I have inquiries made as to where the method is described, and am questioned as to how to succeed with it, when my correspondents know where to find its description. The Editor, also, has asked me to write on the subject, so I propose to put as concisely as I can what plan to adopt. It is almost too well worn a scientific adage to repeat that unless you can obtain a sensitive salt which will absorb the rays to be used photographically, you cannot hope for success; and the method which I shall describe presently fully secures this desideratum. To photograph the red and dark rays then a sensitive salt must be procured which shall absorb the red and ultra-red rays. The colour of the salt to aim at then is a bluish green, which gives a continuous absorption at the least refrangible end of the spectrum. The salt employed is bromide of silver in a modified molecular state, a state I may say which is very easy to obtain when the formula below is strictly carried out, but very easily missed if the experimenter is self-inspired to make improvements in the method of procedure. I don't know whether it is something peculiar to photographic minds that there is in them such a large amount of self-assurance, but my frequent experience is that those who try a formula for a photographic preparation invariably try to improve on it before giving the original one a chance of success: and then when failure occurs they blame everything and everybody except their own conceptions. May I ask those who read this and endeavour to prepare the sensitive compound alluded to, to follow out strictly the directions as I described them in the Bakerian Lecture for 1880.

The following is the mode of preparation. A normal collodion is first made according to the formula below:—

Pyroxyline (any ordinary kind) . .	16 grains
Ether (·725 Sp.)	4 oz.
Alcohol (·820)	2 oz.

This is mixed some days before it is required for use, and any undissolved particles are allowed to settle, and the top portion is decanted off. 320 grains of pure zinc bromide are dissolved in ½ oz. to 1 oz. of alcohol (·820) together with 1 drachm of nitric acid. This is added to 3 ozs of the above normal collodion, which is subsequently filtered. 500 grains of silver nitrate are next dissolved in the smallest quantity of hot distilled water, and 1 oz. of boiling alcohol ·820 added. This solution is gradually poured into the bromized collodion, stirring briskly while the addition is being made. Silver bromide is now partially suspended in a fine state of division in the collodion, and if a drop of the fluid be examined by transmitted light it will be found to be of an orange colour.

Besides the suspended silver bromide, the collodion contains zinc nitrate, a little silver nitrate, and nitric acid, and these have to be eliminated. The collodion emulsion is turned out into a glass flask, and the solvents carefully distilled over with the aid of a water bath, stopping the operation when the whole solids deposit at the bottom of the flask. Any liquid remaining is carefully drained off, and the flask filled with distilled water. After remaining a quarter-of-an-hour the contents of the fla k are poured into a well-washed linen bag, and the solids squeezed as dry as possible. The bag with the solids is again immersed in water, all lumps being crushed previously, and after half-an-hour the squeezing is repeated. This operation is continued till the wash water contains no trace of acid when tested by litmus paper. The squeezed solids are then immersed in alcohol ·820 for half-an-hour to eliminate almost every trace of water, when after wringing out as much of the alcohol as possible the contents of the bag are transferred to a bottle, and 2 ozs. of ether (·720) and 2 ozs. of alcohol (·805) are added. This dissolves the pyroxyline and leaves an emulsion of silver bromide, which when viewed in a film is essentially green-blue by transmitted light.

All these operations must be conducted in very weak red light—such a light, for instance, as is thrown by a candle shaded by ruby glass, at a distance of twenty feet. If a green light of the refrangibility of about half way between E and D could be obtained it would be better than the faint red light transmitted by ruby glass, since the bromide is less sensitive to it than to the latter. The light coming through green glass after being filtered through stained red glass is almost the best light to use. It is most important that the final washing should be conducted almost in darkness. It is also essential to eliminate all traces of nitric acid, as it retards the action of light on the bromide, and may destroy it if present in any appreciable quantities. To prepare the plate with this silver bromide emulsion all that is necessary is to pour it over a clean glass plate, as in ordinary photographic processes, and to allow it to dry in a dark cupboard.

It has been found advantageous to coat the plate in red light, and then to wash the plate and immerse it in a dilute solution of HCl, and again wash, and finally dry. These last operations can be done in dishes in absolute darkness; the hydrochloric acid renders innocuous any silver sub-bromide which may have been formed by the action of the red light, and which would otherwise cause a heated image.

Let me here give warning, that the emulsion formed will be very grainy in appearance, and requires vigorous shaking to cause it to emulsify proper. If it requires a little plain pyroxyline, say about two grains to the